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HOW CAN I BRING THE SOUL OF MATHEMATICS TO MY PUPILS

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To adequately discuss the subject, it seems necessary to define what one means by "the soul of mathematics," or at least to phrase it in another way more definitely suggestive. "Soul" means much to some and little to others of us. Among other definitions, Webster says that "the soul" is "the seat of real life, vitality, or action; the animating or essential part." I believe that this is what we wish to discuss with regard to the teaching of mathematics, so that we may phrase our subject, "How can I bring to my pupils the real vital part of mathematics, the animating, energizing part, the part that has made men devote their whole lives to its study and to wish that they had the more life to live?" The question is one that each one of us needs to answer carefully, thoughtfully, because we will all admit that there is a vast difference between the effects we wish to produce in our pupils and those we do produce.

Do we succeed as teachers if they fail as pupils? Dr. Kilpatrick says, "As teachers we fail if at any time, our children are not disposed and equipped to go on." Taken as they come in various classes, how large a percent of our pupils of mathematics would continue studying the subject if they had their own untrammelled way in the matter? And secondly, how many are equipped to go on? This is a pretty large indictment but there is yet another.

Flexner in "The Modern School" says "A large percentage of our pupils fail (in mathematics) and they take too long a time in doing it." This means that too many fail in mathematics and that it is too costly both to the pupils and the public to carry so many of the pupils so far before they find out that their aptitude and desires carry them into some other field of study.

Both these statements are as true indictments of the teaching of other subjects as they are of the teaching of mathematics, but I have chosen to use them here in order to present the case as vividly as possible. Are they true indictments? Yes, to a large extent. "Disposed and equipped to go on" is a phrase rather carelessly coined so far as meaning and consequences of its literal interpretation go. We do not nor would we want all students to be specialists in mathematics; but we are justified in hoping that we can get all students to realize the permeations of mathematics in the everyday life about them, its importance, and their need of knowing enough of it so that in a given situation in which they are likely soon to find themselves, they will not be at a loss for the fundamentals at least to meet the measurable demands of the situations. We do not want them like a man who can not swim and perchance falls in a well where he has to fight the water to keep it from drowning him; rather we wish them like him who, being able to swim, uses the water to hold himself up until he makes a convenient toe hold, and using it, makes another and another until he finally gets out. We are justified also in hoping that some of our pupils will see the beauties of mathematics, catch the spirit of it, and devote themselves to it, being thereby the better enabled to serve themselves and their fellow men. But how can they do this if it is not first given to them "in spirit and in truth?"

Taking up the second indictment, what are the causes of the failure of pupils in mathematics? I believe that we may attribute a large part of the failure to the fact that the pupils do not begin the subject in the right state of mind, nor do they get the real, vitalizing, energizing spirit of mathematics in many classes. Let us examine the state of mind in which many go at the subject.

A child may hear his father or mother, particularly the mother, in conversation with the neighbors who have children inn school, say, "Oh! I never was any good in arithmetic when I went to school. I suppose that John will have trouble." Consequently, in accordance with the conclusions of Jung, Freud, and other psychoanalysts that the crises of life are to be found in the earliest years and that nothing comes into the mind but what has some connection with all the rest, John is prepared in his mind for failure when he does get in school. One day he does not prepare his lesson satisfactorily. When called to account for it he may truthfully say "I don't know." From letting the one slip, he may go from bad to worse, aided and abetted by his environment at home; and then the excuse verily given becomes, "Well, mother always had a hard time in arithmetic and I suppose I am like her." The unfavorable environment may as well be created by an elder brother or sister, failing in algebra or in geometry, or by being put in a class at school taught by a teacher who has a reputation created by failing pupils. In cases like this, the environment in the home or circumstances at school have turned the child's mind in a direction from which sometimes only the most determined effort on the part of the teacher can reclaim it.

The next point I wish to emphasize is the value of enthusiasm. We have just come through a great war in which, toward the end, the one striking difference between the opposing soldiers was the presence of enthusiasm on the one side and the lack of it on the other. We all know which won, and we all realize in some way the value of enthusiasm to one in athletics, to one in doing his work, to one who is leading others, to one who is away from home. Enthusiasm in any class is an energizing spirit which if guided aright will help in surmounting great difficulties and make up for a multitude of sins. It is only when the sins are very many that we are justified in finding fault with a whole class because there is no other way quite so effective of killing enthusiasm as by finding fault habitually. We ought to be very sure that we ourselves are not guiding our class very poorly if we have to find fault with it publicly very often: most certainly if we wish to talk to individuals, we should do it individually. Summing thus far, if we wish our mathematics to appeal to the pupils, we should cultivate the right attitude on the part of the individual and class, and nourish and guide aright all enthusiasm on the part of either.

Next we need to become acquainted with our pupils, to find them out, to learn their interests. Learning their interests, we naturally appeal to them more, and direct appeal leads to an enthusiastic return. Individual enthusiasm is contagious, and leads to group enthusiasm and interest. Interest leads to effort if properly directed. When a class as a group is putting forth a collective effort to get hold of a new idea, something pleasing to them is bound to come of it, and the effort thus expended leads to new interest. To illustrate—a child may become greatly interested in learning to count. Probably the younger he is, the more pleasure he will take in it. The ability seems to him to be an accomplishment over which he has mastery, giving him a sense of power over a little of the outside world. He compares his new mental state with his previous one and feels a real advance. It gives him pleasure, and therefore he uses it whenever he has opportunity. A little girl having one doll is given another and another. No one could be more proud nor derive more evident satisfaction than the little miss who can and does point to the evidence of it, "I have 'free' dolls." As the acquirement goes on, her number idea grows. For the city child, the number sense grows with counting boats, cars in a train, people in a group; with the country child, similar growth takes place in hunting eggs and telling mother how many there are, countinng the chickens, calves, pigs, and so on. The desire to excel spurs the child to more activity in counting. My own boy, turned loose on the farm, came in with the startling announcement, "Papa, I found 41 eggs today. They didn't find but 26 any day before I came here." This boy had applied his knowledge of counting to an actual situation in which he had found himself where he was in some way connected with breaking a record. It had given him great satisfaction because he could use his knowledge of counting in something that seemed eminently worth while.

For the elementary classes, this experience gives us the hint to teach that mathematics which fills the felt needs of our pupils. Many of us give examples 1-10 on page 63 of the text for tomorrow's lesson and let it go at that. At the start, man was not given a set of books containing knowledge arithmetical, algebraic, or geometrical. Instead of books he was given a more or less philosophical mind with which to think and many forms and groups provocative of thought. Quoting from Hill in "Geometry and Faith," "Many of the geometer's *a priori* laws were first suggested by the laws of nature. Natural symmetry leads us first to investigate the mathematical law which it embodies; then the mechanical law which embodies it." We can show our pupils that man in contemplating nature has thought out laws, then he has gone to nature to verify them and in the doing of it has been provoked to new discoveries resulting in new conclusions and *vice versa.* Through alternations of discovery, proof, discovery, mathematics and natural sciences have grown to be the organized bodies of knowledge that they are today. In the same way as they have grown in the past, they are growing now, and will continue to grow in the future. I believe that nothing stirs a boy or a girl in quite the same way as to discover at the proper time, that mathematics is not a dead, finished subject, but that it is a live, growing one in which men are constantly making new discoveries and applications. In teaching, we can let him discover for himself many of these laws, and he will be filled with a sense of achievement in just the same way as the child learning to count.

This shows us also that we are prone to make too much use of text books in our teaching, and not enough of nature. We don't show the children how natural is the origin of much of our mathematics. How we may do this is shown in a most striking fashion in the ''Illustrated Mathematical Talks by Pupils of The Lincoln School,'' pp. 25-31. The pupils presenting the material there found will always remember it, and they will be talking about it with each other, thus creating a real mathematical atmosphere and propaganda. I have taken a class out-of-doors in New York City with the subject ''Triangles.'' We found them in the shapes of trees in the park, in the leaves, in places where three streets crossed, and saw them in structural work for whole buildings, for holding up scaffolding, fire escapes, keystones for arches, and for ornamentations. Coming home we built a meccano bridge to find out why triangles were so necessary in structural work. For a theme following, New York City was pretty thoroughly searched for triangles, physically, structurally, artistically, and physiologically. One boy said that the profile of a dog's head was a triangle, and drew a figure to prove it. Such a thing is a good thing to do right in the time of this class recitation which we so zealously guard against interruptions; for although the class made no progress in the text book that day, it acquired an impetus that made up several ordinary lessons, and created a spirit of discovery for things mathematical. If mathematics as we teach it pertains directly to the child's environment, helps him to understand it better, makes itself worth while in his work and in his play, the child will appreciate it and be filled with the spirit of it.

For the more advanced classes, say from the end of the ninth school year on, the students of mathematics should be animated by a purpose in their own soul to study the subject. Until this time boys and girls do much of their school work either to please their teacher or their parents, or take it as a matter of course. If they have succeeded in it as the school counts success, they have the added impulse of success and sense of accomplishment to spur them on to do more; if they have not, much or all school work is becoming irksome and they are looking for a substitute. I would not have pupils continue in mathematics beyond the ninth year unless they really liked the subject, unless they were going to college, or unless they were preparing for some particular vocation. Those giving the second reason ought to be made to feel that the colleges were reasonable in making the requirement, and those in the third group ought to see the applications of thir mathematics in the chosen vocation.

After a consideration of real things, let us turn to those of the imagination. The boy who drew the profile of a dog in a triangle was letting his imagination work, and I believe we can the more appeal to the imagination of a child after he has a thorough understanding of the real. With younger boys and girls, we can let this lead on to a discussion of larger things as compared with small, people on other planets, the distances of the stars, and can with propriety and patience answer to the best of our abilities the thousand and one questions that a lively class is sure to ask. In answering these it pays to be absolutely honest and if we don't know the answer to say so. Then we can together look it up and the teacher and class will derive a new pleasure in being co-workers with the same purpose. With these older classes such discussions may well deal with ideas of the infinite, of space or time, something of the nature of which Dr. Smith has indicated to us in the November number of the *Teachers College Record.* In my own classes that know physics, I have felt a preference for introducing here the location of the image of a luminous object found by a double convex lense and trace its movements as the distance of the light giving object from the lense is changed. A class can actually see a good deal of the change with the physical eye, imagination can easily picture the rest, and there is opportunity for so many thought-provoking questions.

Children and young people acquire a greater respect for mathematics if, as the class takes up new subjects or has trouble with old operations, the teacher gives little historical sketches of just how the race overcame this trouble or met that difficulty or tells why this particular process is in the course. All these should be spontaneous. Sometimes it is wise, though, to tell a committee about some historical reference or application, and ask them to look it up for the class. If we wanted to tie a boat very firmly to the wharf, we would run many ropes out preferably to snubbing posts on either side. So the more connections we make between our mathematics in all directions with the life of the past, present, and future, the more do we make its permeations enmesh and enthrall our pupils.

Boys like to make things involving mathematical principles. One of the most instructive things we have had in an intuitive geometry class has been a meccanno set, from which all sorts of forms can be built, and in which imagination can be allowed free play. Boys like to play games, also, in which the use of positive and negative members, the fundamental operations, and other processes, are stressed. It is well to let them get a good deal of drill this way, because mere mechanical drill kills enthusiasm and spontaneity of ideas, two very important parts of good class spirit. Speaking in psychological terms, we may say that the purpose of a child's drill is to reduce the fundamental operations to the plane of habit and using them in a large number of situations they must function as habits, leaving the child's mind free to do the rational thinking required to meet any new situation with which he is confronted. Games furnish a way, not enough used, of giving drill, and they also furnish the teacher an opportunity to step into the background and let the natural leaders of the class come forward.

And now a word for us as teachers. We stand before our classes as living embodiments of the subjects we try to teach. Are we fair in our dealings with our students? Then they would like to be in our classes, no matter what we teach. Do we explain so that with a reasonable amount of effort they can get it? Then they can understand and accomplishment leads on. Do we ever get enthusiastic? Then so will they. Do we ever crack a real joke? Then there must be some likable points somewhere in the stuff. Do we connect mathematics with real men, past, present, with ourselves and the things about us? Then we aren't trying to sell them anything that we ourselves do not buy. Finally, do we ever forget all about our mathematics and disport ourselves as boys or girls or as men or women? Then exposure to our mathematics won't hurt them for a time at least. Is not this way the way most boys and girls size up our subjects and ourselves?

In summing up, the points I have made are these: To bring to our pupils the real, vitalizing, energizing spirit of mathematics, we must cultivate a whole-hearted enthusiasm on the part of the children and of ourselves; we need to present our subject to them not as a cut and dried one but as a living, growing one, permeating all our environment, necessary to a real understanding of and to progress in the life about us, furnishing them and us with real problems that will try our mettle but not too hardly; for man has been meeting them for thousands of years and solving them, yet the wonder of it all is that he has been making the most use of his mathematics in the progress of the last few years. Someone has said, "The true greatness of a work is in the thought which it embodies." We may paraphrase it—"The true worth of our teaching is in the thought which it provokes."